I. C. 6834 APRIL 1935

DEPARTMENT OF THE INTERIOR

UNITED STATES BUREAU OF MINES
JOHN W. FINCH, DIRECTOR

INFORMATION CIRCULAR

THE FERTILIZER INDUSTRIES

G S L

BY

PAUL M. TYLER

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THE FERTILIZER INDUSTRIES[1]

By Paul M. Tyler[2]

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FOREWORD

Modern, scientific agriculture is based upon the mineral industries in much the same way as the industrial and social accomplishments of the modern machine age are predicated upon ample supplies of mineral fuels and metals. A considerable number of chemical elements are required for plant growth and consequently may be classed as fertilizers, but most of them are sufficiently abundant in ordinary soils so that only about three - phosphorus, nitrogen, and potassium - must be supplied artificially, at least regularly and in relatively large amounts.

The Bureau of Mines has already issued separate publications[3] containing detailed information on each of these major elements and also a fourth paper

1/ The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is made: "Reprinted from U.S. Bureau of Mines Information Circular 6834."

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3/ Johnson, B. L., Phosphate Rock: Inf. Circ. 6256, Bureau of Mines, 1930, 64 pp. Nitrogen and Its Compounds: Inf. Circ. 6385, Bureau of Mines, 1931, 33 pp. Potash: Econ. Paper 16, Bureau of Mines, 1933, 78 pp. Minor Mineral Fertilizer Materials: Inf. Circ. 6830, Bureau of Mines, 1935, 35 pp.

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briefly discussing minor fertilizer materials. There is need, however, for a general paper devoted to certain aspects of the industry as a whole and serving both as an introduction and as a supplement to the individual industry reports. Pertinent data and background material for a paper of this sort are presented herein, but the present treatment is preliminary and in places quite sketchy, because studies of this general character have had to be largely discontinued. The drastic reduction in the staff of the Rare Metals and Nonmetals Division precludes additional research on this subject for an indefinite period; accordingly, the paper is offered in its present incomplete form with apologies but nevertheless with the hope that half a report may prove better than none.

A major purpose of this study was to bring into perspective the trends of phosphate rock and potash consumption compared with the total demand for fertilizers. The results tend to show that the United States has been using a relatively larger amount of phosphates than the rest of the world and that the tendency in this country is for the use of potash and nitrogen to increase in relation to the demand for phosphate rock, whereas a larger relative use of phosphates is indicated abroad. Although the present paper suggests this conclusion, it does not contain enough evidence to be accepted as proof.

GENERAL DESCRIPTION AND USES OF FERTILIZERS

To a steadily increasing extent human food supplies depend upon fertilizer supplies. Since time immemorial the flood waters of the Nile annually have provided fresh soil for growing crops, but in practically every other part of the world the maintenance of soil fertility constitutes a problem of prime importance not only to the farmer but also to his community and to the nation to which he belongs. In a purely mechanical way the soil supports and protects growing plants, but it likewise contributes essential chemical material which combines with moisture and other elements supplied from the air and by bacterial action to form the complex structure of vegetal life. At least a dozen different elements are needed to produce ordinary crops, but many of these are required in relatively minute quantities compared with the three major elements. Nitrogen, potassium, and phosphorus are removed fairly rapidly, and unless this loss is made up in some manner the soil becomes exhausted and crop yields grow progressively smaller. If crops are not gathered or consumed on the land by livestock, the herbage on dying down returns to the atmosphere and soil the elements it required during life; and in such instances the soil may in certain cases actually gain, especially in nitrogen. When the crops are utilized, however, plant foods are always drained from the soil, and these must be returned regularly in the form of fertilizer or manure, except perhaps in sparsely settled regions where virgin land can be broken to replace the land that has ceased to yield its quota of crops.

More than 75 percent of grass and an ever larger proportion of certain vegetable crops is water, and the remainder is made up of organic or combustible matter and inorganic or mineral matter. The combustible matter is composed of six elements - carbon, hydrogen, oxygen, nitrogen, sulphur, and a little phosphorus - about one half being carbon. The mineral matter, which

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remains as "ash" when the plant is burned, comprises only a small part of the total plant but contains constituents essential to life and growth. Potassium, calcium, magnesium, iron, phosphorus, and sulphur are present in relatively large amounts, and there are small quantities of manganese and sundry rarer elements, the significance of which has only recently been appreciated as a result in large part of the work of Oswald Schreiner and his associates in the Division of Soil Fertility, United States Department of Agriculture.

By derivation the word "manure" signifies cultivation by manual labor, and in a broad sense it covers all material used for improving land. The term "fertilizer" more specifically implies the function of making the land more productive and is generally employed in the United States to describe plant-food preparations of mineral origin. In England the term "manure" is applied indiscriminately to artificial or manufactured fertilizers as well as to animal manures and other "natural" fertilizing materials. A distinction may often be made between fertilizers as such and "fertilizer materials" which individually contribute the component elements of commercial fertilizers.

So-called complete or mixed fertilizers are combinations containing all three of the principal elements in nitrogen, potassium, and phosphorus.

The relative proportions of these and other elements, however, may be varied, and frequently they are applied to the soil separately. It would be scientifically incorrect to state that one fertilizing element can be freely substituted for another, but from a practical and purely commercial standpoint there is no doubt that a certain amount of substitution actually does take place. Moreover, especially in the case of nitrogen, a variety of fertilizer materials may be employed alternatively as sources of a given element. The following example of possible combination of a complete fertilizer has been presented by Brand.[4/]

The numerals 5-8-7, as employed in describing a mixed fertilizer, indicate the equivalent content of 5 percent of nitrogen as ammonia (NH_3), 8 percent of phosphoric acid (P_2O_5), and 7 percent of potash (K_2O). A natural inference from these figures would be that such a fertilizer contains only the sum of these percentages or 20 percent of actual plant food, but this is not quite true. Even the filler which is quite generally used is not necessarily mere makeweight; it invariably helps to improve the physical condition of the mixture or make it work better in the factory or in the distributing machine, and often it also has some fertilizing or soil-conditioning value. Practically all commercial fertilizer materials, moreover, are natural mixtures or chemical compounds.

4/ Brand, Charles J., Recent Developments in the Fertilizer Industry: Memo. to Committee on Military Affairs, House of Representatives, Washington, D.C., Apr. 10, 1930, p. 4.

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TABLE 1.- Amounts and kinds of materials that may be used in making 1 ton of 5-8-7 complete fertilizer

To furnish			Material, percent	Amount, pounds
Ammonia, percent	Phos. acid, percent	Potash, percent		
1	-	-	Nitrate of soda..... 18	110
3	-	-	Sulphate of Ammonia.. 25	240
1	-	-	Animal tankage..... 8	250
-	8	-	Superphosphate..... 16	1000
-	-	7	Muriate of potash.... 50	280
-	-	-	Filler.....	120
5	8	7		2000

Potassium metal and even pure potash lye would be wholly unsuitable for application to the soil, not merely because they are too expensive. Phosphorus likewise would be not only dangerous but undesirable and inefficient if employed in its elemental state; and nitrogen is already present in superabundance in the atmosphere, though not in a form in which it can be assimilated by most plants. Instead of consisting of 100 percent pure elements, therefore, fertilizer materials generally contain relatively small percentages of their essential constituents. Ordinary superphosphate, for example, inevitably contains roughly 50 percent of synthetic gypsum (calcium sulphate) and an average of only 16 percent phosphoric acid. Commercial nitrate of soda is considered a high-grade fertilizing agent, but it contains scarcely 16 percent of nitrogen or about 19 percent expressed as ammonia equivalent. Even muriate, the highest-grade potassium salt, contains only about 50 percent potash (K_2O), while ordinary manure salts contain 20 percent, and certain low-grade salts only 12.4 to 14.0 percent; in terms of elemental potassium these percentages would of course be reduced further by about one sixth.

In short, there is no such thing as a 100-percent plant food. The tendency, however, is toward the greater use of more concentrated or high-analysis fertilizers. According to Brand,5/ the average plant-food content of commercial fertilizers, which was probably under 12 percent in 1914, increased to 14 percent by 1920 and had advanced to 17 percent by 1930. The last figure includes approximately 4 percent of nitrogen, 10 percent of phosphoric acid, and 3 percent of potash.

According to their total plant-food content fertilizers may be commercially classed into three groups, known as normal, high-analysis, and concentrated fertilizers. The first group comprises all materials and mixtures in which the sum of the nitrogen, "phosphoric acid" (P_2O_5), and potash (K_2O) content is less than 20 percent; the second group comprises all those containing 20 percent but less than 30 percent; and the third group includes all fertilizers that contain 30 percent or more of these essential components.

5/ Brand, Charles J., work cited, p. 6.

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PHOSPHORUS

The most important mineral element used in fertilizers is phosphorus. Its principal function seems to be connected with the maturing of the plant. It appears in the seed or fruit and in grains tends to increase the ratio of grain to straw. Although it is not ordinarily considered as contributing to the growth of plant structure it is also described as a stimulant to young plants.

Phosphate rock, the main source of phosphatic fertilizers, occurs very abundantly in the United States, and this country has been by far the leading producer, supplying not only the large domestic demand but also a substantial export market. The yield of French colonies, especially in North Africa, has grown rapidly in importance, and since the World War the aggregate output of France and her possessions frequently has exceeded one half the total world output. American producers no longer dominate foreign markets, and imports have invaded the home market. Exports, principally from Florida land-pebble fields, have by no means ceased - in fact, in recent years they have closely approached pre-war levels - but compared to the worldwide increase in consumption they are relatively of much less consequence.

Phosphate rock, being insoluble or practically so, generally is treated with sulphuric acid to form the superphosphate, which is soluble and hence absorbed more promptly by the rootlets of plants. Bone meal and high-phosphorus slags from the iron and steel industry (especially slag from the Thomas-Gilchrist or basic bessemer process used extensively in continental Europe) are phosphatic fertilizers, which are of some importance and do not have to be acidulated.

POTASH

In most of its effects potash resembles phosphorus, as its benefits are principally evidenced in the seed and fruit rather than in stem and leaf development. However, it does improve fiber plants and strengthens stalks, tends to improve the keeping quality of fruits and vegetables, and has other valuable properties. A proper balance of plant nutrients is of greatest importance. Although the specific functions of any component cannot always be stated, potash is universally considered one of the most essential ingredients of a complete fertilizer.

A variety of potash-bearing materials are utilized as plant foods, including certain marine (kelp) and land vegetation and various minerals. Although potassium is an essential constituent of animal life, the only commercial source of potash of animal origin is the dried oily sweat (suint) removed in scouring wool. The bulk, perhaps 90 percent, of the world consumption of potassium salts is in the form of chlorides, although a relatively small amount of sulphates and a smaller quantity of nitrates are consumed in agriculture; all of these salts are obtained principally from salt beds or natural brines. The world situation as of recent years has been described 6/

6/ Johnson, B. L. Potash: Econ. Paper 16, Bureau of Mines, 1933, p. 31.

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as a nearly complete monopoly by a Franco-German-Polish combination of the government-controlled potassium salt industries of the three leading European producing nations, with several other nations striving with varying degrees of success to make themselves independent. Subsequent developments in Spain and Russia have modified this picture, and during the last 2 or 3 years the United States has developed large domestic supplies which definitely relieve the former dominance of foreign supplies and are considered in some quarters as possibly forecasting an exportable surplus.

Minor quantities of potash salts are recovered as byproducts of the beet-sugar industry (from Steffens waste) and of wool washing. Wood ashes constituted one of the earliest sources, and California kelp has likewise been utilized. Flue dusts from iron blast furnaces and cement plants have also been treated for potash, and various processes have been devised for extracting potash from silicate rocks and from certain insoluble or complex salts, notably polyhalite.

NITROGEN

Nitrogen is an essential constituent of practically all forms of vegetable and animal life. On many soils it is the limiting element of plant food in the soil and is considered to be particularly necessary to the formation of stem and leaf, contributing materially to vegetable and stalk growth.

The atmosphere is the great reservoir of nitrogen, and millions of tons of this gaseous element lie superimposed upon every acre of the earth's surface. This nitrogen, however, is inert; none of the higher forms of plants or animals can utilize it directly. It must first be converted into compounds or "fixed" in combination with other elements. There are bacteria and other micro-organisms that do this, and great quantities of nitrogen are thus made available to the higher forms of plant life and to animals that feed upon these plants. This process is constantly operating, but like many of nature's processes it is far too slow to keep up with the heavy drain made by modern methods of cultivation. The use of natural manure on farm lands is almost universal, but this practice returns to the soil only part of the nitrogen originally removed in crops or by grazing. Additional returns are made in the form of various waste materials of both animal and vegetable origin. In the fertilizer industry wide use is made of such materials as cotton-seed meal, castor pomace, bone and meat meal, animal tankage, dried blood, fish scrap, garbage tankage, leather scrap, and a score or more nitrogenous materials, and organic nitrogen stored away in past ages in coal is likewise reclaimed in the form of ammonium sulphate and ammoniacal liquor from by-product coke and gas manufacture. Additional large quantities of nitrogen are supplied in the form of sodium nitrate from Chile. This material, which has been utilized as fertilizer since the early part of the 19th century and which has been actively exploited since the early 1880's, was for a long time the only commercial source of inorganic nitrogen for agriculture. Ammonium sulphate from byproduct-coke manufacture was a later development, and inasmuch as the output of byproduct nitrogen is limited by factors other than the

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demand for nitrogen the world monopoly enjoyed by the Chilean industry was not even questioned until the World War occasioned the development of synthetic nitrogen-fixation plants that draw their supplies of raw material from the atmosphere. Although the early development of the air-nitrogen industry received its main impetus as a result of risks of wartime shipments overseas and an abnormal demand for nitrogenous explosives, it has subsequently managed to compete on progressively more favorable terms with industries employing compounds and materials whose nitrogen has been fixed by natural processes. With inexhaustible supplies of free nitrogen everywhere available the chemical engineer now produces nitrogenous fertilizers as well as nitric acid and its salts in whatever quantities and as speedily as market conditions demand. Chilean nitrate no longer sets the price level, and it remains to be seen to what extent the reorganized Chilean industry can compete in the world markets.

Ammonia in its various forms constitutes the main source of nitrogen in the United States; the domestic output, estimated in terms of nitrogen, increased from 76,000 short tons in 1921 to 274,000 tons or more in 1929. Imports of nitrogen still consist mainly of Chilean nitrate but include increasingly large quantities of calcium cyanamide and minor quantities of other compounds. In 1929 the total imports represented about 240,000 short tons of nitrogen. Exports in that year were equivalent to 44,000 short tons of nitrogen, most of which was ammonium sulphate. In the form of commercial nitrogen the domestic consumption, therefore, was apparently around 470,000 tons. It should be remembered that this figure does not include nitrogen contained in farmyard manure and sundry other noncommercial sources. Organic ammoniates are becoming less and less important factors in nitrogen supply. The output of such materials has not kept up with the rapid growth in the world requirements of nitrogen, and the supply available to the fertilizer industry has been curtailed further due to the fact that more remunerative markets have been found for many of these items. Cottonseed meal, for example, is extensively used as stock feed.

Changes in the sources of nitrogen are indicated in the following table, which gives figures compiled from original sources by P. E. Howard in the monograph on Fixed Nitrogen edited by A. H. Curtis (p. 470), for selected years:

TABLE 2.- World production of nitrogenous materials
(short tons of nitrogen)

	1913	1924	1929
Byproduct sulphate of ammonia	384,160	292,000	413,600
Other byproduct ammonia	-------	55,200	56,100
Cyanamide	67,200	1/114,000	231,000
Synthetic sulphate of ammonia	-------	254,000	533,500
Nitrate of lime	28,000	20,000	149,600
Other synthetic nitrogen	-------	56,200	401,500
Chilean nitrate of soda	436,800	372,300	539,000
	916,160	1,162,700	2,324,300

1/ Excluding cyanamide made in Japan, which in 1924 is included under synthetic sulphate of ammonia.

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Nitrogen, in addition to its extensive use in fertilizer, has important industrial uses and is a vitally necessary war material, being an essential constituent of virtually all explosives. In peace times approximately 90 percent of the world's supply of commercial nitrogen is used in agriculture and 10 percent in industry. In the United States the proportion used in industry is considerably greater than in the world at large, as indicated by the following tabulation which, however, relates only to inorganic nitrogen.

TABLE 3.- Distribution of consumption of inorganic nitrogen in the United States for specified years 1/
(short tons of nitrogen)

	1899	Percent	1914	Percent	1928	Percent
Fertilizers	8,900	29.8	92,200	59.8	301,000	72.5
Explosives	13,850	46.8	32,500	21.1	22,500	5.4
Chemicals and acids	5,910	20.0	22,600	14.7	56,500	13.6
Miscellaneous industries ..	0	----	130	----	21,000	5.1
Refrigeration	1,000	3.4	6,830	4.4	14,000	3.4
	29,660	100.0	154,260	100.0	415,000	100.0

1/ Howard, P. E., Curtis monograph, p. 488.

HISTORY OF FERTILIZER INDUSTRY

Long before recorded history it was generally known that exhaustion of the soil might be in a measure prevented by allowing a field to lie fallow every third season, the effect being to provide time for rock particles in the soil to weather and yield soluble salts that plants would assimilate. The ancients also learned to grow certain grasses and plow them back into the soil, as is done now with clover to supply nitrogen. Farmyard manures and even wood ashes were spread on the land to increase crop yields in quite early times. Although the manufacture and sale of fertilizers constitute an industry of relatively recent growth their fundamental function of enriching the soil is almost as old as agriculture itself. The rapid development of the industry in recent years is based not so much upon the discovery of new principles as upon the explanation of underlying causes, which in turn led to the discovery of ways and means for supplying economically the essential elements of plant food.

The use of chemical fertilizers probably dates from 1669, when Sir Kenelm Digby wrote that he had increased the yield of crops by the application of saltpeter, but it was not until 1804 that DeSaussure first directed scientific attention to the fact that the ash ingredients of plants were taken from the soil and that they were, in the main, essential to plant growth.1/ A few years later - in 1809, according to some authorities - Taddeo Haenke, a German resident of Bolivia, called attention to the beneficial effects of natural nitrate as an agricultural fertilizer. Exportation to Europe began in 1830, but commercial development proceeded slowly until the nitrate beds were seized by Chile during the war with Bolivia, 1879-81.

1/ Collings, Gilbert H., Commercial Fertilizers: Philadelphia, 1934, p. 1.

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In 1840, J. von Liebig, the famous German chemist, published the results of certain discoveries regarding the use of chemicals to stimulate the growth of plants and suggested treating bones with sulphuric acid to make them more available as fertilizers. In 1843 (after patenting the process in 1842), Sir John Lawes in England began to manufacture superphosphate by acidulating mineral phosphates. This was the beginning of the phosphate-rock industry; the original material was the so-called coprolites found in Cambridgeshire, Suffolk, and Bedfordshire. About the same time ammonia salts began to be made as a byproduct at gas works, and Peruvian guano likewise appeared on European markets. The necessity for supplying plants with nitrogen, however, was not recognized until 1857, when Lawes, Gilbert, and Pugh, of the Rothamsted Experiment Station, England, definitely established the essential nature of the element.[8] The first potash shaft was sunk in the Stassfurt district in Germany in 1851, borings having been made in the previous decade, but the value of potash in agriculture was not recognized then, and the potassium and magnesium salts overlying the rock salt were called "Abraumsalze", or worthless salt, and were rejected. However, as von Liebig's researches were extended to potash, the value of these deposits was recognized and processes were speedily devised to extract their potash content. In 1861, A. Frank erected the first works for the extraction of potassium chloride; and the industry began to make rapid strides, even before the Franco-Prussian War. The larger companies found it necessary to undertake to regulate the industry as early as 1878, but it was not until 1888 that the first potash syndicate was formed.

Chemical fertilizers were produced in the United States for the first time in Baltimore, and according to Brand[9] some 20,000 tons of artificial fertilizers were manufactured in the United States as early as 1856. The Federal Census for 1859 included the fertilizer industry, which was credited with $891,000 worth of finished products reported by 47 firms.

ECONOMIC SERVICES

The object in using fertilizers is obviously to raise the yield of crops. The advantage so gained is represented by the difference between the value of the increase of crop resulting from the use of fertilizer and the additional cost, including not only the cost of the fertilizer but also that of spreading it on the fields and harvesting the increased yield.

The following tables, based on nation-wide surveys by the National Fertilizer Association, indicate the mass opinions of 48,000 American farmers in different sections of the country with regard to their experience relative to specified crops. Warner[10] has stated that $1 spent for fertilizer will

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8/ Collings, G. H., work cited, p. 1.
9/ Brand, Charles J., work cited, p. 1.
10/ Warner, H. W., Interpretation and Popular Presentation of Data Showing Economic Results of Fertilization: Jour. Am. Soc. Agron., vol. 23, April 1931, p. 266.

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show a return averaging $2 to $5. Naturally the best results are obtained from soils that are in the best condition for plant growth - neither too fine nor too coarse, too wet nor too dry, to compact nor too porous.

TABLE 4.- Crop returns from the use of commercial fertilizer during 1927

Crop	Value of crop produced by fertilizer	Fertilizer used, tons	Estimated cost of fertilizer	Increase in value for each dollar spent for fertilizer
Cotton	$295,890,000	2,108,000	$64,553,000	$4.71
Corn	106,352,000	1,510,000	44,612,000	2.38
Tobacco	104,963,000	470,000	15,697,000	6.69
Potatoes	87,151,000	688,000	26,215,000	3.32
Wheat	56,671,000	682,000	20,515,000	2.76
Citrus	19,303,000	241,000	9,650,000	2.00
Oats	18,111,000	326,000	9,833,000	1.84
Sweet potatoes	16,871,000	112,000	3,739,000	4.51
Vegetables and fruits	16,240,000	146,000	5,146,000	3.16
Miscellaneous crops	14,622,000	148,000	4,626,000	3.16
Hay	9,693,000	185,000	5,740,000	1.69
Tomatoes	8,476,000	78,000	2,907,000	2.92
Total	$754,343,000	6,694,000	$213,233,000	$3.54

Source: National Fertilizer Association, American Fertilizer Practices: 1929, p. 147.

TABLE 5.- Crop returns, by sections, from the use of commercial fertilizer during 1927

State groups	Added value produced by fertilizer	Fertilizer used, tons	Estimated cost of fertilizer	Increased crop value for each dollar of fertilizer cost
New England	$32,757,000	363,135	$15,401,000	$2.13
Middle Atlantic 1/	127,124,000	1,390,680	44,561,000	2.85
Southeastern 2/	469,068,000	3,828,620	117,750,000	3.99
Southwestern 3/	36,268,000	248,760	9,371,000	3.87
Middle Western 4/	89,126,000	863,600	26,150,000	3.41

Source: Collings, G. H., Commercial Fertilizers: Philadelphia, 1934, p. 281. (Compiled from data obtained by National Fertilizer Association.)

1/ New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, West Virginia.

2/ North Carolina, South Carolina, Georgia, Florida, Tennessee, Alabama, Mississippi.

3/ Arkansas, Louisiana, Texas.

4/ Ohio, Indiana, Kentucky, Michigan, Illinois, Wisconsin, Minnesota, Iowa, Missouri.

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WORLD REQUIREMENTS

According to McBride,11/ the world uses about 50 million tons of fertilizers yearly, with an aggregate value between two thirds and one billion dollars and containing almost 8 million tons of the plant-food constituents. Of the latter quantity roughly 1,500,000 tons, say 20 percent, is used in the United States. Farmers in some European countries use much more fertilizer per acre than American farmers. The Muscle Shoals Commission (1931), for example, estimated that in 1927 the consumption of plant food - nitrogen, phosphoric acid, and potash - per acre of cultivated land was about 10 pounds in the United States, 33 pounds in France and Great Britain, 70 pounds in Germany, and 105 pounds in the Netherlands.

The following table shows by countries the world consumption in 1928 of the three leading plant nutrients, as compiled by Howard (1930) of the Fixed Nitrogen Research Laboratory. Germany leads in total consumption and in consumption of nitrogen and potash. The United States ranks second in total consumption and second in consumption of nitrogen and potash but first in consumption of phosphoric acid. Three countries, the United States, Germany, and France, account for 56 percent of all the plant food used in the world. European countries consume two thirds of the total tonnage; North America takes about one fifth; Asia, Australia, and the Pacific Islands use about one tenth; Africa and South America now employ scarcely 3 percent of the apparent total.

Neither population, land area, nor output of agricultural products indicates the relative distribution of fertilizer consumption by countries.

11/ McBride, R. S., Mineral Economics Lectures, under the auspices of the Brookings Institution (edited by F. G. Tryon and E. C. Eckel): New York, 1932, p. 137.

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TABLE 6.- World consumption of nitrogen, phosphoric acid, and potash by countries, in 1928

Country	Nitrogen (N), tons	Phosphoric acid (P_2O_5), tons	Potash (K_2O), tons	Total, tons
Germany	450,000	566,000	818,000	1,834,000
United States 1/	345,000	800,000	343,000	1,488,000
France	160,000	583,000	210,000	953,000
Japan	190,000	180,000	50,000	420,000
Italy	62,000	250,000	27,500	339,500
Netherlands	82,000	125,000	115,000	322,000
Great Britain 2/	49,000	165,000	60,000	274,000
Spain	75,000	140,000	55,000	270,000
Poland	52,000	100,000	80,000	232,000
Belgium	70,000	40,000	43,000	153,000
Czechoslovakia	32,000	84,000	36,500	152,500
Australia	4,000	128,000	500	132,500
Denmark	34,000	40,000	16,000	90,000
Sweden	15,000	38,000	30,000	83,000
Egypt	41,000	17,000		58,000
Union of South Africa	6,500	41,000	3,000	50,500
New Zealand	2,500	41,000	4,500	48,000
Finland	3,000	31,000	14,000	48,000
Formosa	32,000	12,000	750	44,750
Algeria	2,000	30,000	7,000	39,000
U.S.S.R. (Russia)	10,000	27,000		37,000
Irish Free State	4,000	30,000	2,500	36,500
Hungary	4,000	28,000	1,500	33,500
Switzerland	1,000	26,000	6,000	33,500
Dutch East Indies	32,000			32,000
Canada	6,000	18,000	7,000	31,000
China	30,000			30,000
Portugal	2,500	27,000		29,500
Austria	5,000	18,000	6,000	29,000
Norway	4,000	14,000	9,000	27,000
Latvia	1,000	15,500	4,000	20,500
Lithuania	500	15,000	2,000	17,500
Jugoslavia	3,500	13,000	1,000	17,500
Korea	17,000			17,000
Ceylon	5,000	6,000	5,000	16,000
Greece	1,000	6,000	2,000	9,000
Esthonia	500	5,000	2,500	8,000
Philippines	6,000	500		6,500
Canary Islands	4,000			4,000
India and Burma	4,000			4,000
Cuba	3,500			3,500
All others	49,500	76,000	64,250	189,750
	1,901,000	3,736,000	2,025,500	7,662,500

Source: Collings, G. H., Commercial Fertilizers: Philadelphia, 1934, p. 16. (Original data by P. E. Howard.)

1/ Including Puerto Rico and Hawaii.

2/ Including North Ireland.

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As a result of the world depression, consumption of chemical fertilizers dropped to a record low in 1932 but recovered substantially in 1933, as shown by the following table:

TABLE 7.- Index figures for world consumption of inorganic fertilizers[1/]

Consumption of	1924 to 1928 (ave.)	1929	1930	1931	1932	1933
Nitrogen (agricultural only)	100	145	152	126	122	139
Potash (K_2O).....	100	128	126	92	84	98
Phosphoric acid (P_2O_5) as phosphate rock and basic slag.....	100	118	112	76	71	86

1/ U.S. Bureau of Foreign and Domestic Commerce., World Trade Notes on Chemicals and Allied Products: Vol. 8, no. 25, June 15, 1934, p. 1.

The relative gain in the use of nitrogen, increasingly from synthetic sources, is noteworthy, while potash consumption remained practically stationary and phosphoric acid apparently declined.

DOMESTIC PRODUCTION

The production of fertilizers in the United States, as reported by the Federal Census, increased fairly steadily from 727,453 short tons valued at $19,921,400 in 1879 to 8,432,206 short tons valued at $153,260,212 in 1914. Tonnage figures are not available for the two earliest fertilizer censuses, those of 1859 and 1869, but from the values reported ($891,344 and $5,815,118, respectively) quantities of approximately 30,000 and 150,000 tons are indicated for these early years. Growth since 1914 has been almost imperceptible on the basis of tonnage figures, but measured in terms of plant-food content the production continued to expand at a fairly rapid rate until after 1929. In 1929, 9,320,229 short tons of commercial fertilizers of all kinds, valued at $222,731,116, were made and marketed, an increase of only 12½ percent in quantity and a decrease of 22½ percent in value compared with the previous high record of 1919, but the estimated increase in the content of nitrogen, phosphoric acid, and potash was fully 25 percent. Complete fertilizers now constitute a large percentage of total sales, and the average total plant-food content of these fertilizers, as shown by Mehring and Peterson,[12/] increased steadily to 14.9 percent in 1910, dropped slightly to 13.9 percent in 1920, and has since risen rapidly to 18.0 percent in 1932.

The Census figures shown in the following table include all manufactured products intended to promote the growth of plants but exclude such items as raw phosphate rock, crude cottonseed, ordinary tankage, and unground bone.

12/ Mehring, A. L., and Peterson, A. J., Changes in Composition of American Fertilizers, 1880-1932: U.S. Dept. Agriculture Circ. 315, April 1934, 20 pp.

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TABLE 8.- Production of fertilizers in the United States, 1899-1931, by kinds

(Source: U.S. Bureau of Census)

Year	Total fertilizers		Complete fertilizers		Superphosphates 1/		All other Fertilizers	
	Tons	Value	Tons	Value	Tons	Value	Tons	Value
1899	2,887,014	$42,097,673	1,622,474 1/	$28,781,883 1/	937,008	$8,592,360	327,532	$4,723,430
1904	3,591,771	56,928,034	2,385,201 1/	44,325,882 1/	786,767	7,821,096	419,803	4,781,056
1909	5,618,234	100,089,971	3,523,759 1/	74,109,307 1/	1,494,097	16,458,344	600,378	9,522,320
1914	8,432,206	153,260,212	5,612,421 1/	121,676,386 1/	1,760,290	16,145,659	1,059,495	15,438,167
1919	8,284,553	287,715,214	4,756,440 1/	200,106,419 1/	2,515,281	50,050,347	1,012,832	37,558,448
1921	6,038,849	176,599,717	3,324,487 1/	122,926,533 1/	1,976,742	33,598,364	737,620	20,074,820
1923	7,625,517	179,949,655	4,222,400 1/	124,135,404 1/	2,458,118	33,204,439	944,999	22,609,812
1925	8,229,032	195,040,157	5,057,651 1/	146,605,516 1/	2,638,761	35,180,160	532,620	13,254,481
1927	8,122,723	173,809,773	5,162,991 1/	130,310,176 1/	2,434,516	30,003,438	525,216	13,496,159
1929	9,320,229	222,731,116	5,991,780	168,838,463	2,531,230	28,375,184	797,219	25,517,469
1931	6,967,681	140,717,901	4,544,650	110,172,501	1,968,153	20,678,216	454,878	9,867,184
1933								

1/ Includes ammoniated fertilizers.
2/ Includes concentrated phosphates.

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Trends of the fertilizer industry for the pre-war and post-war periods and for the intervening interval are shown by the index numbers of physical volume of production and selling price per unit of production, as calculated from the Census data by F. C. Mills.13/ From 1899 to 1914 he finds the rate of growth of production averages 7.8 percent annually, a net increase of 196.4 percent in 15 years. For the post-war period 1923 to 1929 he calculates the annual rate of growth at only 4.2 percent, and inasmuch as production subsequently dropped off sharply a similar calculation that included the depression years would show a negative change. By the same process Mills calculated an average gain in unit values of 1.3 percent annually for the pre-war period and a decline of 1.0 percent during the post-war years 1923-29, inclusive.

TABLE 9.- Fertilizer manufacture by decades, 1859 - 1929
(Source: Bureau of the Census)

Year	Number of establishments				Fertilizer production, total for all industries			
	Fertilizer industry alone		All industries		Quantity		Value	
	No.	Increase, percent	No.	Increase, percent	Short tons	Increase, percent	Dollars	Increase, percent
1859	47	-	-	-	-	-	$891,344	-
1869	126	168	-	-	-	-	5,815,118	552
1879	364	189	-	-	727,453	-	19,921,400	243
1889	390	7	-	-	1,898,806	161	35,519,841	78
1899	422	8	475	-	2,887,004	52	42,097,673	19
1909	550	30	843	77	5,618,234	95	100,089,971	138
1919	600	9	809	-4	8,284,553	47	287,715,214	187
1929	638	6	-	-	9,320,229	13	222,731,116	-23

LOCALITIES OF PRODUCTION

Over 50 percent of the total output of fertilizers in the United States is produced in the South Atlantic States; Maryland, Georgia, North Carolina, Virginia, and South Carolina were the leading producers in 1931. The Middle Atlantic States were formerly second in importance but have been outstripped by the rapid growth in production in the North Central and South Central divisions. The geographical distribution of production by groups of States and kinds of fertilizers is shown in table 11, which gives tons and value, and the distribution of establishments by States appears in table 12.

Georgia leads all States in the number of plants; but most of them are small, so that Maryland often leads in number of wage earners and in fertilizer production, even though it has scarcely one third as many plants.

13/ Mills, F. C., Economic Tendencies in the United States: 1932, 639 pp.

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TABLE 10.- Geographical Distribution of Production, 1899-1909, 1919, 1929
(Source: Bureau of the Census)

States and Census year	Total fertilizers		Complete fertilizers		Superphosphates	
	Tons	Value	Tons	Value	Tons	Value
U. S. total						
1899	2,794,605	$40,545,661	1,579,580	$27,895,434	923,198	$8,471,943
1909	5,618,234	100,089,971	3,523,759	74,109,307	1,494,097	16,458,344
1919	8,284,553	287,715,214	4,756,440	200,106,419	2,515,281	50,050,347
1929	9,320,229	228,731,116	5,991,780	168,838,463	2,531,230	28,375,184
New England						
1909	60,358	1,577,631	45,227	1,219,703	-	-
1919	110,944	7,524,508	108,425	7,406,237	787	23,477
1929	312,912	9,887,091	234,913	8,248,813	50,199	508,965
Middle Atlantic						
1899	685,893	11,978,666	452,950	9,475,000	139,232	1,320,000
1909	878,956	14,590,414	536,264	11,088,516	257,913	2,271,862
1919	629,704	22,418,571	408,932	17,216,835	105,404	2,138,105
1929	767,373	22,371,721	425,234	12,061,429	93,589	891,903
South Atlantic						
1899	1,531,688	19,462,816	773,021	12,460,000	622,614	2,900,000
1909	2,867,799	49,979,300	1,661,833	34,734,499	857,720	10,017,211
1919	5,072,858	178,283,513	3,049,347	131,522,338	1,653,919	31,542,829
1929	5,303,104	115,463,309	3,593,513	95,602,481	1,512,210	15,087,667
North Central						
1899	258,726	4,349,157	140,198	2,460,000	62,945	815,000
1909	351,196	6,471,512	246,253	4,878,011	61,365	916,763
1919	916,464	27,047,406	449,206	14,377,796	271,634	6,574,482
1929	1,127,079	29,086,008	666,952	19,703,746	241,884	3,566,024
South Central						
1899	352,778	5,053,564	214,646	3,590,000	110,649	1,140,000
1909	816,436	12,648,037	474,076	8,854,666	285,949	2,885,143
1919	966,011	29,146,157	447,229	16,840,986	389,286	8,006,889
1929	1,568,388	38,424,055	973,452	29,243,570	412,605	5,580,732
Western						
1899	22,131	636,687	19,570	628,000	-	-
1909	62,619	2,062,428	43,913	1,766,476	14,420	159,203
1919	82,105	4,212,595	53,314	2,977,292	13,388	192,784
1929	241,373	7,498,032	97,711	3,978,424	7,577	115,722
Undistributed						
1899	35,788	616,783	22,088	397,000	1,568	18,000
1909	202,800	5,040,309	182,983	4,763,221	37,875	706,552
1919	458,925	15,911,773	239,987	9,764,935	80,863	1,571,781
1929					213,166	2,624,171

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TABLE 11.- Number of fertilizer factories, by classes, in the United States, 1928

State	Number of cities having fertilizer plants	Number of plants					
		A 1/	B 2/	C 3/	D 4/	Unclassified	Total
Northeastern:							
Maine	8				8	2	10
Vermont	1				1		1
Massachusetts	8	2	1	1	9	1	14
Rhode Island	1				1		1
Connecticut	6				7	1	8
New York	9		1	2	7	1	11
New Jersey	21	2	3	1	18	1	25
Pennsylvania	27	3	3	12	20		38
Delaware	6				7		7
Maryland	21	7	5	3	28	1	44
Lake:							
Ohio	13	8	12	2	4	2	28
Indiana	13		7	3	6		16
Illinois	4	3	2	3			8
Michigan	3		1		1	1	3
Wisconsin	2			2			2
Southeastern:							
Virginia	17	6	3	3	25	4	41
West Virginia	2				2		2
Kentucky	2		2	1	4		7
Tennessee	7	4	4		2		10
North Carolina	50	11	7	1	64	3	86
South Carolina	33	11	7		47	4	69
Georgia	97	19	21	1	135	3	179
Florida	13	3	3	1	16	2	25
Alabama	44	12	9		57	1	79
Mississippi	11	5	2		6		13
South Central:							
Arkansas	9	1	1		11		13
Louisiana	7	3	3		8		14
Texas	14	2		2	15		19
California	13	3		4	20		27
All other States	20	1	2	12	16	1	32
Total United States	482	106	99	54	545	28	832

Source: Collings, G. H., Commercial Fertilizers: Philadelphia, 1934, p. 266.

1/ Complete fertilizer plant, with acid chambers, superphosphate, and mixing equipment.

2/ Superphosphate and mixing plant, with rock-grinding, acidulating, and mixing equipment (without acid chambers).

3/ Ammoniate and mixing plant, manufactures ammoniates only, but has mixing equipment (without acid chambers, rock-grinding, or acidulating equipment).

4/ Dry-mixing plant, with mixing equipment, which buys all ingredients.

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Ordinary dry-mixing plants, equipped only to mix materials purchased from other plants or imported, may be located almost anywhere but usually are designed to serve a local market. In many Southern States such local plants are small partly because cottonseed crushing and fertilizer mixing go well together but also because applications per acre are moderate. On the other hand, highly concentrated demand for potato growing in Maine and for tobacco in Connecticut favors the development of relatively large local plants.

The location of acidulating plants for making superphosphates and certain nitrogen products is dictated in many instances by nearness to mines or by-product plants producing phosphate rock or certain ammoniates, but cheap acid is also a factor. Water-transport facilities, combined with relatively short rail distance to important consuming centers, have contributed to the establishment of plants in Maryland, in New Jersey, and in Florida, and several other Southern States.

Maryland is by far the largest distributor of fertilizers in interstate trade. Virginia, New Jersey, Georgia, Ohio, and Illinois also ship important quantities to other States.

SIZE OF ESTABLISHMENTS

In all industries there seems to be an optimum size of individual operations. The number of fertilizer factories increased rapidly from 47 in 1859 to a maximum of 784 in 1914, while the value of the average output per plant advanced from about $19,000 during the year of the first census (1859) to $195,000 at the outbreak of the Great War in Europe 55 years later. In 1919, due to higher prices as well as to a large mortality among the smaller plants, the average output per plant reached a maximum of $468,573, more than 54 percent of the total output being supplied by plants producing over $1,000,000 worth of fertilizers during the year, as against less than 17 percent from such large plants in 1909 and 24 percent in 1914. A study of the available figures for production according to size of establishment shows an increase in number of establishments of all sizes from 1904 to 1914 and in 1919 a marked decline in the number of plants producing less than $100,000 worth of products annually, a less-marked decline in those of the $100,000 to $500,000 group, and an increase in number and aggregate output in the larger plants.

The 1921 depression resulted in a decrease in the number of plants and output in the larger plants, but the number of establishments producing less than $100,000 increased (doubtless due to lower prices) and the total value of products manufactured in plants of this size group likewise increased slightly.

From 1921 to 1929 there were increases in the number of plants and output in the classes above $20,000.

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TABLE 12.- Number of fertilizer establishments, according to value of products, 1904 - 29
(Source: Bureau of Census)

Value of products	1904	1909	1914	1919	1921	1923	1929
Less than $5,000.....	46	54	50	16	18	(1)	(1)
$5,000 - $20,000.....	87	95	130	59	74	61	32
$20,000 - $100,000.....	131	180	296	143	182	178	194
$100,000 - $500,000)	129	211	(225	202	227	214	258
$500,000 - $1,000,000)			(59	94	69	84	106
$1,000,000 and over....	6	10	24	86	36	36	48
Total.....	399	550	784	600	606	573	638

1/ Not tabulated.

Since 1919 the value of the average output per establishment in the fertilizer industry, as shown by the following table, has remained in the vicinity of $250,000 to $360,000. The Census figures included establishments producing less than $5,000 worth of products before 1919 but not after that year. This change in policy would have tended to exaggerate the apparent average output per plant were it not for the fact that the number of these small plants has dropped to insignificant proportions and the value of their product to a negligible percentage of the total.

TABLE 13.- Number of fertilizer establishments and average value of output, 1859 - 1931

Year	Number of establishments	Average value of output	Year	Number of establishments	Average value of output
1859	47	$18,965	1919	600	$468,573
1869	126	46,152	1921	606	297,737
1879	364	64,975	1923	573	319,527
1889	390	100,464	1925	587	352,254
1899	422	105,823	1927	621	306,578
1904	399	141,707	1929	638	364,437
1909	550	187,667	1931	599	257,679
1914	784	195,403	1933		

Data on the quantity of fertilizers produced within the fertilizer industry are not published by the Census Bureau, so the tonnage production per fertilizer-industry plant cannot be obtained.

The tonnage of all fertilizers produced in the United States, which combines both the fertilizers produced in the fertilizer industry and those produced as secondary products in other industries, is reported by the Census Bureau. From 1899 to 1923, inclusive, the Census Bureau likewise reported the number of fertilizer-producing establishments, both within and without the fertilizer industry, so that for those years actual tonnage figures per fertilizer-producing plant are available. Since 1923 the number of plants producing fertilizer as secondary products of other industries has not been reported by the Census Bureau. In 1919, 1921, and 1923 these plants formed

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approximately 26 to 29 percent of the total number of plants, and the value of the products in those years formed 4.5 to 8.8 percent of the total value of the fertilizers produced in all industries, and in the years since from 4.1 to 9.4 percent of the total value. The average value of fertilizer production and the average tonnage per plant for the years for which the data are available are shown in the accompanying table. The average production per plant before the World War was 6,000 to 7,000 tons. In 1919 it reached 10,240 tons, and even in 1921 and 1923 it was substantially above the pre-war level. At the 1929 peak the average was probably higher than in 1919 despite a considerable increase in number of plants.

TABLE 14.- Average value and tonnage per fertilizer-producing plant in all industries

Year	Total number of plants	Average value per plant	Average tonnage per plant (short tons)
1899	475	$88,627	6,078
1904	552	103,130	6,507
1909	843	118,731	6,665
1914	1,238	123,797	6,811
1919	809	355,643	10,240
1921	827	213,543	7,302
1923	789	228,073	9,665

MATERIALS CONSUMED IN THE MANUFACTURE OF FERTILIZERS

A variety of materials is used as sources of nitrogen, phosphorus, and potassium in the preparation of fertilizers. The principal materials and the quantities used annually since 1899 are shown in table 15.

FOREIGN TRADE

The United States exports large quantities of phosphate rock and substantial quantities of other fertilizer materials and mixed fertilizers. The value of exports in 1929 was over 20 million dollars, or nearly 10 percent of the value of domestic output. Nevertheless, imports exceed exports by a wide margin; in 1929, they were nominally valued at over 72 million dollars, a figure that would be even larger if valuations were on an American instead of foreign market basis - that is, if freight and other costs of importation and delivery to consuming plants were included.

Nitrogenous materials represent the main group of fertilizer materials obtained abroad. By far the leading item is nitrate of soda, and although imports of this Chilean material have tended to decrease, imports of other nitrogenous materials have increased or at least held their own. Nitrate of soda, it should be noted, has other uses than for fertilizer; these generally account for over one third of the imports, but this condition does not alter the fact that despite the development of synthetic nitrate plants, an export surplus of byproduct ammonium sulphate and a huge output of organic nitrogenous materials, this country has a large net deficit of fixed nitrogen which

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TABLE 15.- Material consumed in fertilizer manufacture, by kind and quantity, for the United States, 1899 - 1931
(short tons)

(Source: Bureau of the Census)

Material	1899	1904	1909	1914	1919	1929	1931
Superphosphate made and consumed.....	(1)	884,211	1,838,865	2,723,317	3,316,486	1,601,685	1,524,618
Superphosphate purchased	286,898	320,559	532,886	1,096,178	1,200,182	1,368,031	1,077,279
Phosphate rock	787,927	888,571	1,549,497	2,080,961	2,247,325	2,291,037	1,780,397
Sulphur	12,728	4,210	4,236	2,041	221,558	339,088	269,517
Pyrites	288,788	342,962	456,574	613,842	398,602	201,384	148,593
Sulphuric acid made and consumed	(1)	692,904	841,935	1,276,715	1,568,577	1,373,033	1,102,629
Sulphuric acid purchased	231,527	197,865	620,708	728,889	636,632	922,150	633,860
Bones	(1)	(1)	(1)	148,191	169,711	45,676	24,817
Manure salts	(1)	(1)	(1)	108,580	17,560	389,884	274,422
Muriate of potash	(1)	(1)	(1)	177,372	32,900	228,319	192,984
Sulphate of potash	(1)	(1)	(1)	39,232	79,482	77,043	63,554
Kainite	54,700	190,493	347,104	448,885	31,145	81,119	49,101
Other potash materials	(1)	(1)	(1)	209,226	154,135	90,497	83,511
Total potash materials	(1)	312,600	617,563	983,295	315,222	866,862	663,572
Sulphate of ammonia	4,120	10,540	65,592	149,924	135,882	460,505	322,878
Nitrate of soda	19,518	42,213	89,846	162,184	152,415	240,403	106,284
Calcium cyanamide	(1)	(1)	(1)	25,911	16,926	77,389	39,509
Cottonseed meal	(1)	(1)	(1)	325,234	230,526	84,762	55,340
Guano(all kinds)	(1)	(1)	(1)	120,128	33,053	40,807	26,134
Fish scrap and meal	(1)	(1)	242,045	250,110	273,252	149,887	43,579
Tankage and dried blood	(1)	(1)	(1)	(1)	(1)	221,460	168,617
Tankage and ammoniates not otherwise specified	(1)	(1)	842,557	887,934	689,753	- -	- -

1/ Data not available.

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is met by imports. Potash salts comprise another large group of imports and one that was increasing perceptibly before domestic mines came into production. Phosphatic materials constitute the only major group in which imports are generally small and exports large. The main item in this group is bone phosphates (bone ash, bone dust, bone meal) and animal carbon for fertilizer. This class of material and dried blood as well are derived principally from the slaughterhouses of Argentina and Uruguay. Tankage, too, comes mainly from the same sources, although Canada and other countries also furnish fairly large amounts.

Canada supplies practically all the calcium cyanamide imported, but other synthetic nitrogen products come from Germany and Norway. Guano is supplied mainly from Peru and Argentina, but fairly large imports under this category have been credited in the statistics for some years to European countries also. The classification of "other nitrogenous material" includes hoof meal, castor-bean pomace, fish scrap, cod-liver meal, and whale meal from various sources, also urea and sundry synthetic products from Germany. This classification, as well as that of tankage, includes some material that is not used for fertilizer, but only in small amount, as even individual importations of higher-grade material, if used chiefly for feed, are not admitted free of duty, even though the words "used only for manure" as employed in the Tariff Act of 1913 were altered in par. 1583 of the act of 1922 to "used chiefly for fertilizer."

Germany formerly supplied the world's potash and still is the leading source of imports of crude potash salts into the United States, although other countries, notably Spain, are increasingly important. Larger domestic production since 1930 has tended to reduce the quantity of both crude and refined potash salts purchases abroad.

Imports of phosphate rock have been relatively small and have originated chiefly in French Oceania and Morocco.

One fourth to one third of the domestic production of phosphate rock, chiefly Florida land pebble, is exported; European countries, especially Germany, take the major part of the tonnage, although recently Japan has become the outstanding foreign buyer of domestic phosphate rock. Canada, Cuba, and Japan are the foremost buyers of superphosphates. Next to phosphate, ammonium sulphate is the principal export item as regards tonnage, and usually it is the leading item in value. Before the World War large quantities of this material were imported, but subsequently domestic production from byproduct-coke plants has greatly increased to permit heavy exports, especially from Middle Atlantic ports; exports go largely to the Far East, notably Japan, Java, and the Philippine Islands, where it is used extensively to fertilize rice fields. Potash fertilizers, mostly muriate, are exported, but only in rather small amounts, chiefly to Japan and Canada. Concentrated chemical fertilizers and prepared mixtures have quite a wide distribution, but far eastern countries account for the bulk of the shipments.

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Practically all fertilizers and fertilizer materials are exempt from duty, and accordingly some of the domestic exports probably represent foreign materials transshipped with little or no processing in this country. However, variable quantities of these materials are statistically classed as foreign exports, comprising transshipments mainly of sodium nitrate but also some potash salts and miscellaneous fertilizers and materials. This trade is almost wholly with Canada, only minor amounts being forwarded to Mexico and negligible amounts to other nearby countries.

The tables showing imports and exports by grand divisions show that our exports to Europe comprise principally material (phosphate rock) of low unit value as compared with the more highly manufactured products shipped elsewhere. In 1929, Europe accounted for considerably over one half the tonnage but less than one fourth the value of the exports. In former years the comparison was even more striking; the trend seems to favor a larger exportation of products having higher unit values, whereas the average unit values of imported fertilizer materials of all kinds show a general decline. By further reducing imports of potash and nitrates from Europe and South America and increasing exports to Asia and less-industrialized countries generally the foreign trade balance may be equalized more nearly on a dollar basis.

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TABLE 16. - Fertilizer imports for consumption, by kinds, 1914, 1924, and 1929

Class	1914 1/		1924		1929	
	Long tons	Value	Long tons	Value	Long tons	Value
Total	2,029,767	$46,305,650	1,892,845	$66,534,033	1,892,845	$66,534,033
Sodium nitrate	554,047	17,926,165	986,638	47,171,947	930,458	34,913,254
Calcium nitrate	(2)	(2)	7,682	347,304	31,684	1,256,589
Calcium cyanamide	29,536	1,590,004	75,558	3,687,794	184,260	6,220,996
Sulphate of ammonia	74,640	4,900,058	6,000	342,000	19,052	773,356
Ammonium sulphate-nitrate	---	---	(2)	(2)	16,284	883,787
Guano	21,853	754,727	25,241	754,234	45,905	2,202,709
Dried blood	3/ 8,000	391,931	7,195	404,314	9,773	696,221
Tankage	(2)	(2)	21,717	676,201	20,779	814,255
Other nitrogenous materials	(2)	(2)	47,355	1,084,788	69,039	2,655,444
Bone phosphates and animal carbon	41,446	1,036,493	22,242	706,727	55,877	1,624,483
Phosphate rock, crude	23,551	177,838	16,098	181,515	44,899	469,171
Apatite	92	796	--	--	--	--
Basic slag	9,509	108,565	703	9,598	3,998	54,456
Phosphate materials, crude, n.s.p.f.	(2)	(2)	1,861	35,902	40	1,221
Potash, muriate, crude	234,855	7,925,781	129,128	3,982,288	230,966	8,224,661
Potash, sulphate, crude	44,985	1,887,491	75,696	2,858,063	79,510	3,647,839
Kainite	526,112	2,579,619	156,708	923,740	75,930	643,950
Manure salts, hard salts	260,976	2,757,013	231,248	2,278,484	390,828	5,113,085
Ashes, wood, and beet root	3/ 3,000	27,884	1,541	17,583	675	9,313
Other potash materials	(2)	(2)	41,922	410,670	--	--
Fertilizer mixture	(2)	(2)	1,730	83,290	5,379	408,814
Limestone, ground	(2)	(2)	--	--	5,679	22,562
Other substances used only for manure	197,165	4,241,285	36,582	577,591	89,000	1,714,448

1/ Fiscal year ended June 30, 1914. 2/ Not listed separately. 3/ Estimated.

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TABLE 17. - Total imports of fertilizers, by grand divisions, 1914, 1924, 1929

Division	1914		1924		1929	
	Tons[1/]	Value	Tons	Value	Tons	Value
Europe	1,200,000	$24,584,341	791,664	$16,498,461	1,026,224	$27,274,880
North America	47,000	2,642,126	44,987	1,118,142	242,025	7,585,033
South America	760,000	18,786,952	1,036,703	48,454,302	989,194	36,474,349
Asia	9,000	214,353	5,143	167,474	12,040	408,022
Oceania	21,000	153,532	10,975	149,166	21,254	347,925
Africa	--	--	3,408	143,950	19,038	249,565
Total	2,037,000	$46,381,304	1,892,880	$66,531,495	2,309,775	$72,339,774

1/ Partly estimated; only values reported in statistics for certain items.

TABLE 18. - Fertilizer exports from the United States, by kinds, 1914, 1924, and 1929

	1914[1/]		1924		1929	
	Long tons	Value	Long tons	Value	Long tons	Value
Total	1,539,472	$11,978,738	1,068,325	$16,508,398	1,534,295	$20,440,677
Sulphate of ammonia	(2)	(2)	118,367	6,918,598	144,761	6,295,519
Other nitrogenous materials	(2)	(2)	4,699	283,154	24,358	1,229,995
Phosphate rock, hard	475,335	4,753,350	150,746	1,814,194	67,474	473,031
Phosphate rock, land pebble, etc.	1,002,536	5,864,485	668,027	3,306,638	1,075,272	4,913,888
Superphosphates	(2)	(2)	45,751	588,620	85,118	1,489,476
Potash materials	(2)	(2)	(2)	(2)	13,868	582,690
Prepared mixtures	(2)	(2)	35,793	1,695,472	33,508	1,795,918
Other fertilizers	61,609	1,360,903	44,942	1,901,722	89,936	3,660,160

1/ Fiscal year ended June June 30, 1914. Totals cover only items separately listed and consequently may be incomplete.
2/ Not separately listed.

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TABLE 19. - Total exports of fertilizers, by grand divisions, 1914, 1924, and 1929

Division	1914[1]		1924		1929	
	Long tons	Value	Long tons	Value	Long tons	Value
Europe	1,388,902	$10,122,371	720,745	$ 4,911,278	872,863	$ 4,893,268
North America	60,545	1,253,225	186,783	5,097,829	207,551	4,274,280
South America	231	14,168	408	31,518	1,731	130,769
Asia	89,147	568,162	153,630	6,420,485	450,671	11,062,931
Oceania	489	17,200	25	2,210	677	30,530
Africa	158	3,612	6,734	45,078	802	48,898
Total	1,539,472	$11,978,738	1,068,325	$16,508,398	1,534,295	$20,440,677

1/ Fiscal year ended June 30, 1914. Totals cover only items separately listed and consequently may be incomplete.

PLANT-FOOD CONTENT

The true picture of fertilizer consumption is not revealed by tonnage figures. Some materials of low plant-food content (notably organic ammoniates) are no longer available for fertilizers or are available in much smaller quantities, superphosphate and sundry other fertilizer materials (especially superphosphate and kainite) are now supplied in more concentrated form, and there is an all-around tendency to employ mixed fertilizers of higher analysis. The following table, comparing estimated consumption of fertilizers with estimated consumption of the three principal components on the basis of averages for 5-year periods, tends to show that the consumption of mineral phosphates and nitrogen increased roughly twice as fast as the total fertilizer tonnage between the pre-war period (1910-14) and the post-war maximum (1925-29), whereas the use of potash (K_2O content) in fertilizers progressed at approximately the same rate as the total tonnage. The latter condition, however, is attributable to what may have been an abnormal consumption of potash immediately before the World War. Inspection of the figures leads to the conclusion that total plant food consumption increased over 40 percent whereas tonnage consumption increased only 22.4 percent. During the World War and for some years thereafter the supply of potash was seriously reduced; and the more recent trend indicates that the use of potash is increasing greatly compared to the aggregate fertilizer tonnage, whereas phosphate consumption tends merely to keep pace with the total, and nitrogen consumption is making relatively slight gains.

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TABLE 20. - Estimated consumption of fertilizers and specified materials by 5-year periods, 1910-29

Item	Five-year averages, short tons				Percent increase 1925-29 v.	
	1910-14	1915-19	1920-24	1925-29	1910-14	1920-24
Phosphate rock	1,751,797	1,997,900	2,064,811	2,536,978	44.8	22.9
Superphosphate	3,150,000	3,492,000	3,612,000	4,456,133	41.4	23.4
Potash (K_2O)	245,778	40,237	191,327	302,195	22.9	57.8
Nitrogen (N)	215,000	175,000	244,000	309,000	43.7	26.7
Total fertilizer sales	6,135,854	5,892,945	6,195,363	7,514,149	22.4	21.3

In Europe the general ratio of nitrogen, phosphorus, and potash has been estimated by various authorities as about 1.0 N : 2.0 P_2O_5 : 1.0 K_2O.[14/] The data given in the foregoing table take no account of phosphate sources other than phosphate rock, but especially in recent years phosphate rock has supplied most of the phosphate for fertilizer purposes, so little error is introduced by using it as an index, especially since the diminishing importance of organic phosphate materials is largely offset, if not more than offset, by an upward tendency in the B.P.L. content of phosphate-rock production. For the 1925-29 period a reasonable estimate of P_2O_5 consumption may be made by dividing the consumption of phosphate rock (average around 72 percent B.P.L.) by 3, and accordingly the tonnage of leading plant-food ingredients consumed in fertilizers in the United States was of the order of 309,000 tons of N, 840,000 tons of P_2O_5, and 302,000 tons of K_2O. This works out to an N:P:K ratio of roughly 1 : 2.75 : 1. In other words, American farmers evidently use a higher proportion of phosphates in their fertilizers than European farmers.

The National Fertilizer Association and subsequently the U. S. Department of Agriculture have investigated trends in the consumption and analyses of mixed fertilizers. It was found that the plant-food content of the materials used in mixed fertilizers has increased in recent years. For example, the average percentage of available phosphoric acid in superphosphate in 1880 was 11.01, in 1910 it was 15.68, and in 1932 it was 18.31. In recent years about 60 percent of the total tonnage of fertilizers sold has consisted of complete mixed goods. The only other kind of mixture used in considerable quantities is that containing available phosphoric acid and potash. This kind represents only 2 percent of the total consumption, but it is interesting to note that the average analysis of such mixtures has progressively increased as regards potash content but only slightly as regards available phosphoric acid. In 1880

14/ Great Britain, Italy and France are relatively large consumers of phosphate but the average is heavily weighted by the heavy consumption in Belgium, Germany and other countries that use more nitrogen and potash.

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the average composition of superphosphate and potash mixtures was 11.5 percent available phosphoric acid and 2.0 percent potash; in 1932 the corresponding figures were 12.8 and 8.2 percent.

Based upon "more than a million published determinations," Mehring and Peterson[15/] summarize their findings as follows:

> The average complete mixed fertilizer in 1880 contained 2.3 percent of nitrogen, 8.9 percent of available phosphoric acid, 2.2 percent of potash, and 13.4 percent of total available plant food. In 1932 these figures were 3.4 percent of nitrogen, 9.5 percent of available phosphoric acid, 5.1 percent of potash and 18.0 percent of total available plant food. Figures for intermediate years have been given and show that most of the changes in composition have occurred in the last 10 years. Like figures for phosphate and potash mixtures show that changes of similar character and extent have occurred in them also. In 1880 the average complete mixed fertilizer included 1.7 percent, in 1925, 0.6 percent, and in 1932, 0.8 percent more plant food than it was guaranteed to contain.
>
> In 1900 the nitrogen in all mixed fertilizers was derived 2.1 percent from ammonium salts, 6.9 percent from nitrates and 91 percent from organic ammoniates. In 1931, 61.2 percent was derived from ammonia and its compounds, 11.6 percent from nitrates, 18.8 percent from organic ammoniates, and 8.4 percent from cyanamide and urea. The source of each of the plant-food elements in mixtures has been given for a number of years.
>
> In 1880 practically no filler was used in mixtures. In 1931 the average content of filler in mixed fertilizers was 15.2 percent. If no filler had been used such fertilizer would have contained over 21 percent of plant food instead of 17.9 percent.
>
> The statistics collected in this study show that in some States very little change has been made in the average grade of fertilizers consumed, and that much filler is now used in mixtures. In other States, the average analysis of mixed fertilizers has steadily increased since 1920, and very little filler is used. The highest average analyses were found in those sections where farmers have only recently begun to use fertilizers.

Consumption trends in Europe indicate an important gain in the position of nitrogen with respect to phosphoric acid and potash and at the same time disclose a relatively larger use of potash in many foreign countries as compared with practice in the United States. France, like the United States, has been a relatively large user of phosphatic fertilizers, and a study of French

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15/ Mehring, A. L., and Peterson, A. J., Changes in Composition of American Fertilizers, 1880-1932: U. S. Dept. of Agriculture Circ. 315, April 1934, p. 19.

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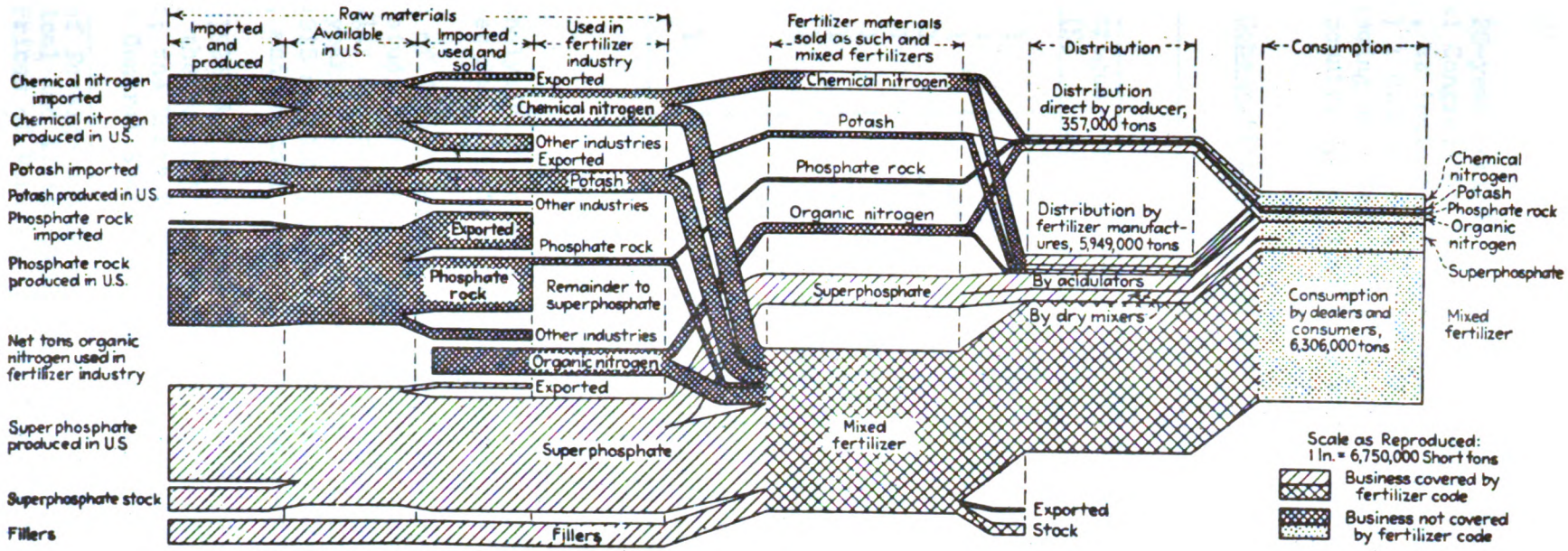

Figure 1.—Flow chart showing, for the year 1931, importation and production of fertilizer materials and their distribution and use, direct and in mixed fertilizers (National Fertilizer Assoc.); from Chem. and Met. Eng., January 1934, p. 33.

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consumption for a 20-year period, as reported in a paper[16/] presented at the Industrial Chemical Congress at Lille, shows steady gains in nitrogen and potash consumption, as indicated by a change in the index relationships from 1 (N) : 4.45 (P_2O_5) : 0.43 (K_2O) in 1913 to 1 (N) : 2.24 (P_2O_5) : 1.17 (K_2O) in 1932. The following data from the same paper show recent changes for 8 leading consuming countries, together with an average for 23 European and African countries:

TABLE 21. - Consumption ratios of leading plant-food constituents in specified countries

	1929			1931		
	Nitrogen (N)	Phosphoric Acid (P_2O_5)	Potash (K_2O)	Nitrogen (N)	Phosphoric Acid (P_2O_5)	Potash (K_2O)
France	1	3.07	1.38	1	2.44	1.20
Italy	1	3.75	.18	1	3.50	.175
Great Britain	1	4.20	1.21	1	3.93	1.325
Spain	1	2.67	.248	1	2.38	.242
Denmark	1	2.17	.40	1	2.60	.654
Netherlands	1	1.33	1.35	1	1.50	.925
Germany	1	1.44	1.79	1	1.33	1.435
Belgium	1	1.10	.79	1	.725	.650
Average for 23 European and African countries	1	2.20	1.28	1	2.00	1.15

DOMESTIC CONSUMPTION

A graphical analysis of sources and distribution of fertilizer materials in the United States for 1931 is shown in Figure 1.

Tonnage sales of fertilizers in the United States for the 26 years 1900 to 1925 have been studied in detail by Vial[17/]. A rapid growth averaging 350,000 tons annually occurred from 1900 to 1914, after which there were wide fluctuations from year to year but no consistent increase. The largest fluctuations were in 1915 and 1921, following the big cotton crop of 1914 and the deflation of 1920, and amounting to 1,800,000 and 2,400,000 tons respectively.

From 1909 to 1925 the South Atlantic States consumed about 56 percent of the total tonnage; the North Atlantic States, 18 percent; the South Central States, 14 percent; the North Central States east of the Mississippi River, 8 percent; the North Central States west of the Mississippi River, 1 percent,

16/ U. S. Bureau of Foreign and Domestic Commerce, Abstracted in World Trade Notes on Chemical and Allied Products: Vol. 7, no. 48, Nov. 27, 1933, p. 1.

17/ Vial, E. E., Prices of Fertilizer Materials and Factors Affecting the Fertilizer Tonnage: Cornell Univ. Agric. Exper. Sta. Memoir 119, December 1928, pp. 85-90.

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and the Far Western States, 1 percent. About 75 percent of the tonnage was consumed along the Atlantic seaboard, where in general the soils are of comparatively low natural fertility and where rainfall is heavy. In much of this area the leading money crops are cotton, tobacco, potatoes, and truck. During this 17-year period there were important increases in tonnage consumption in States where cotton production was profitable and where acreage was expanding, such as North Carolina, Mississippi, Arkansas, and Texas - in the northern and western part of the Cotton Belt. The tobacco-producing States - Virginia, Kentucky, Tennessee, and Connecticut - also used more tonnage, as did also those developing a large market-garden business in vegetables and potatoes, including Florida, Michigan, and Maine. The largest increases, expressed in percentages, were in Washington and Wisconsin, but due to the small quantities consumed in these States they had no appreciable effect on the national total, which received its main impetus from North Carolina, Florida, and Ohio. Large decreases in tonnage were reported in the eastern Cotton-Belt States - Alabama, South Carolina, and especially Georgia, where boll-weevil damage has made inroads on growers' income. In States where dairying and general farming prevail the use of fertilizers failed to show notable change.

Vial also calculated the coefficients of variability of fertilizer consumption for various regions. Violent decreases in tonnage naturally increase the risk of fertilizer companies doing business in such regions and react unfavorably upon the farmer who has to pay more for his fertilizer in the long run to make up the losses dealers suffered in years when sales were poor or collections slow. This statistical study shows a high degree of variability in the South Atlantic and South Central States, especially the older cotton-growing States, and only small variability, indicating a fairly dependable demand year after year, in the North Atlantic States. High variability is also observed in other regions but does not represent a menace to profits, inasmuch as it merely reflects increasing demand.

After 1925 the tonnage sales of fertilizer increased irregularly until 1930 and then dropped sharply. In 1932 they fell to the lowest point since 1905, and the upturn in 1933 and 1934 was quite gradual. Inasmuch as the depression more than canceled apparent gains since the World War the question remains whether total consumption in tons follows a horizontal or a slightly rising trend. West of the Mississippi, in New England, in North Carolina, and possibly in other States the secular movement appears to be definitely upward, but conditions in the heart of the old Cotton Belt, where so large a proportion of the total consumption is still concentrated, are less easily appraised. Political restraint or regimentation of production of certain crops further complicates any attempt to peer into the future. Tabular data are accordingly submitted herewith without additional comment.

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TABLE 22. - Distribution of total sales of fertilizers, pre-war and post-war

Region	1910-14 1/		1925-29 1/		Percent increase in sales 2/
	Tons sold	Percent of total tons	Tons sold	Percent of total tons	
United States	6,135,854	100.0	7,513,641	100.0	22.4
New England	251,490	4.1	352,617	4.7	40.2
Middle Atlantic	731,118	11.9	739,267	9.9	1.1
East North Central	401,592	6.5	733,716	9.8	82.7
West North Central	54,036	.9	91,521	1.2	69.3
South Atlantic	3,697,374	60.3	3,955,065	52.6	7.0
East South Central	753,003	12.3	1,121,478	14.9	48.8
West South Central	198,727	3.2	383,950	5.1	92.8
Mountain	20	.0	5,039	.1	25,100.0
Pacific	48,494	.8	130,988	1.7	171.0

1/ Average. 2/ Post-war v. pre-war.

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TABLE 23. - Estimated sales of fertilizer in the United States by regions, 1910-32

Year	New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific
1910	208,400	654,600	339,256	33,795	3,343,888	674,388	153,396	-	44,500
1911	230,000	694,900	379,539	44,685	3,717,410	718,237	185,070	-	53,700
1912	243,600	718,816	352,962	45,359	3,465,226	714,398	172,055	-	54,500
1913	274,500	759,461	444,075	69,380	3,757,438	761,840	228,278	-	42,000
1914	300,950	827,814	492,130	76,960	4,202,906	896,150	254,838	100	47,771
1915	287,020	746,074	457,552	70,060	3,052,836	550,154	119,316	300	39,950
1916	284,200	674,935	399,207	52,440	3,036,141	434,795	204,771	500	37,915
1917	307,550	801,292	425,137	77,200	3,580,620	479,301	200,264	700	52,964
1918	309,200	791,496	558,068	103,700	3,796,271	635,690	230,525	1,200	40,036
1919	285,200	773,085	667,436	115,537	3,896,839	620,269	212,151	1,700	53,126
1920	351,421	747,747	671,407	114,787	4,268,833	694,479	247,720	1,980	78,380
1921	319,388	714,771	551,388	63,430	2,691,577	355,497	82,131	1,620	83,129
1922	347,486	748,634	634,183	64,721	3,037,634	601,406	147,577	1,955	86,319
1923	345,709	716,239	617,065	67,997	3,488,819	852,659	266,627	2,380	84,819
1924	355,768	722,512	640,806	64,971	3,741,099	863,192	353,209	2,580	80,774
1925	360,656	728,148	694,517	83,952	3,927,484	1,091,317	340,179	2,980	103,933
1926	316,700	698,045	679,001	82,874	3,921,678	1,141,275	371,090	3,553	114,052
1927	363,147	728,149	718,948	83,574	3,686,528	880,123	253,137	3,833	125,768
1928	365,119	743,558	755,711	99,565	4,191,219	1,255,676	422,930	4,558	146,683
1929	357,465	798,433	820,402	107,638	4,048,417	1,239,001	532,415	10,272	164,505
1930	366,840	778,160	788,274	109,714	4,122,695	1,325,969	485,039	10,690	176,489
1931	362,594	697,927	598,468	93,275	3,309,019	841,684	228,396	13,870	160,849
1932 1/	316,218	607,500	379,143	49,024	2,353,563	408,102	103,834	10,021	134,390

1/ Preliminary.

Source: Compiled from State data published by National Fertilizer Association.

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TABLE 24. - Estimated sales of fertilizers in the United States by regions, 1910-32

(Index numbers, 1923-25 = 100)

Year	U. S.	New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountains	Pacific
1910	79.4	58.9	90.6	52.1	46.7	89.9	72.1	47.9	-	49.5
1911	87.7	65.0	96.2	58.3	61.8	100.0	76.8	57.8	-	59.8
1912	84.0	68.8	99.5	54.2	62.7	93.2	76.3	53.8	-	60.7
1913	92.3	77.5	105.1	68.2	96.0	101.0	81.4	71.3	-	46.7
1914	103.4	85.0	114.6	75.6	106.4	113.0	95.8	79.6	3.8	53.2
1915	77.5	81.1	103.3	70.3	96.9	82.1	58.8	37.3	11.3	44.5
1916	74.6	80.3	93.4	61.3	72.5	81.6	46.5	64.0	18.9	42.2
1917	86.3	86.9	110.9	65.3	106.8	96.3	51.2	62.6	26.4	59.0
1918	94.2	87.3	109.6	85.8	143.4	102.1	67.9	72.0	45.3	44.6
1919	96.5	80.6	107.0	102.6	159.8	104.8	66.3	66.3	64.2	59.1
1920	104.5	99.3	103.5	103.2	158.7	114.8	74.2	77.4	74.8	87.2
1921	70.8	90.2	99.0	84.7	87.7	72.4	38.0	25.7	61.2	92.5
1922	82.6	98.1	103.6	97.4	89.5	81.7	64.3	46.1	73.9	96.1
1923	93.8	97.6	99.2	94.8	94.0	93.8	91.1	83.3	89.9	94.4
1924	99.4	100.5	100.0	98.5	89.9	100.6	92.2	110.4	97.5	89.9
1925	106.8	101.9	100.8	106.7	116.1	105.6	116.6	106.3	112.6	115.7
1926	106.7	89.5	96.6	104.3	114.6	105.4	122.0	116.0	134.2	126.9
1927	99.7	102.6	100.8	100.5	115.6	99.1	94.1	79.1	144.8	140.0
1928	116.3	103.1	102.9	116.1	137.7	112.7	134.2	132.2	172.2	163.3
1929	117.6	101.0	110.5	126.1	148.9	108.9	132.4	166.4	388.1	183.1
1930	118.9	103.6	107.7	121.1	151.7	110.9	141.7	151.6	403.9	196.4
1931	91.8	102.4	96.6	92.0	129.0	89.0	90.0	71.4	524.0	179.0
1932	63.5	89.3	84.1	58.3	67.8	67.3	43.6	42.4	378.6	149.6
1933	70.2	-	-	-	-	-	-	-	-	-
1934										
1935										

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TABLE 25. - Fertilizers used on various crops in 1927 1/

(Figures include fertilizers applied as side and top dressing and total represents 97.5 percent of all fertilizer used in the United States in 1927)

Crop	Short tons	Percentage of total	Crop	Short tons	Percentage of total
Cotton	2,108,000	31.4	Rye	18,000	.3
Corn	1,509,000	22.5	Peaches	3/15,000	.2
Potatoes	688,000	10.3	Sweet corn	14,000	.2
Wheat	682,000	10.2	Rice	4/13,000	.2
Tobacco	470,000	7.0	Strawberries	13,000	.2
Oats	326,000	4.9	Beans (dry)	12,000	.2
Citrus fruits	2/ 241,000	3.6	Cucumbers	8,000	.1
Hay	184,000	2.7	Soy beans	7,500	.1
Sweet potatoes	112,000	1.7	Cabbage	6,000	.1
Tomatoes	78,000	1.2	Cantaloupes	4,500	.1
Vegetables (Miscellaneous)	60,000	.9	Sugar beets	4,500	.1
Peanuts	49,000	.7	Onions	4,500	.1
Buckwheat	26,000	.4	Cowpeas	3,000	-
Watermelons	22,000	.3	Sugar cane	2,000	-
Barley	20,000	.3			

1/ National Fertilizer Association, American Fertilizer Practices: 1929, p. 85.
2/ Florida only.
3/ Georgia only.
4/ Louisiana only.

SEASONAL VARIATIONS IN SALES

Inasmuch as farmers purchase fertilizer only a short while before planting time, sales of fertilizer are highly seasonal. Ordinarily over three fourths of the fertilizer sales are made during the first 4 months of the year. In many States more than half the sales are made in a 6-week period that includes March. Missouri is an exception, as sales reach their peak in that State in September. Fall tonnage, although of less importance than the spring tonnage, also is sold in Virginia, North Carolina, and Louisiana. Index numbers of seasonal variation in tag sales by leading States shown in the accompanying table have been calculated by Vial[18], who points out a tendency for seasonal variations to become more violent in the post-war period. Quantities of fertilizer are purchased with loans from local banks, and buying naturally is postponed as long as possible.

18/ Vial, E. E., work cited, p. 102.

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TABLE 26. - Index numbers of seasonal variation in tag sales

State	Period	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Alabama	1921-25	106	281	557	198	9	2	1	1	2	3	10	29
Georgia	1921-25	172	304	530	163	11	3	1	1	2	4	3	7
Do.	1912-16	182	338	455	160	12	7	1	0	3	12	9	20
Louisiana	1921-25	193	372	334	112	29	6	4	5	60	69	39	57
Do.	1910-14	273	267	307	120	41	10	3	7	96	29	10	39
Missouri	1921-25	65	90	85	27	16	4	153	265	474	21	1	1
North Carolina	1921-25	126	221	451	268	37	13	3	6	21	26	5	23
Do.	1910-14	113	185	414	305	47	27	9	3	30	44	7	16
South Carolina	1921-25	198	321	478	107	16	10	3	3	7	13	15	29
Do.	1910-14	246	380	388	67	18	19	10	5	11	17	16	24
Virginia	1921-25	173	161	200	268	58	22	31	77	123	55	4	29
Do.	1910-14	138	133	186	268	93	16	16	116	164	44	5	22

PRICES

The accompanying tables bring out the fact that prices of fertilizers were relatively higher than prices of other commodities during and for a short period after the World War, but that since about 1921 they have been consistently lower. Throughout the past decade and more the complaint has been that the purchasing power of the farmer has suffered compared with the "real wages" of labor and capital in other industries. The exchange value of farm products in terms of fertilizers has remained much higher than it was during the so-called "normal" period before 1914.

Census data show a permanent increase in average values per ton of domestic production, but this is attributable to the steady increase in average plant-food content and generally greater service value of products sold.

TABLE 27. - Average value, per short tone, of domestic production, 1859-1931

Year	Value per ton	Year	Value per ton
1859	$28.00 1/	1919	$34.73
1869	38.00 1/	1921	29.24
1879	27.39	1923	23.60
1889	18.71	1925	23.70
1899	14.58	1927	21.40
1904	15.85	1929	23.90
1909	17.82	1931	20.20
1914	18.18	1933	

1/ Estimated.

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TABLE 28. - Wholesale price indexes of specified groups of commodities, 1913-33

(1926 = 100)

Year	All commodities 1/	Chemicals 1/	Farm products 1/	Fertilizer materials 1/	Mixed fertilizers 1/	Potash 2/	Phosphate rock 2/
1913	69.8	89.4	71.5	85.5	84.3	(3)	112
1914	68.1	91.0	71.2	78.3	85.5	(3)	104
1915	69.5	127.8	71.5	133.7	92.0	726	87
1916	85.5	196.9	84.4	205.2	142.2	1010	88
1917	117.5	187.6	129.0	228.0	137.7	993	89
1918	131.3	187.3	148.0	236.9	195.0	950	97
1919	138.6	145.8	157.6	191.8	221.7	570	150
1920	154.4	166.5	150.7	211.6	177.1	417	180
1921	97.6	108.9	88.4	117.9	162.5	235	175
1922	96.7	97.2	93.8	102.3	119.0	95	128
1923	100.6	100.6	98.6	102.5	107.4	94	114
1924	98.1	102.2	100.0	92.6	95.9	89	105
1925	103.5	104.1	109.8	98.8	100.4	108	98
1926	100.0	100.0	100.0	100.0	100.0	100	100
1927	95.4	100.0	99.4	96.2	93.0	114	105
1928	96.7	101.5	105.9	94.6	97.3	116	105
1929	95.3	99.1	104.9	92.1	97.2	120	103
1930	86.4	93.7	88.3	85.6	93.6	122	105
1931	73.0	83.0	64.8	76.8	82.0	112	108
1932	64.8	79.5	48.2	66.9	69.3	87	99
1933	66.0	79.6	51.4	65.9	64.5	88	93
1934							

1/ U. S. Bureau of Labor Statistics.
2/ Based on average value of domestic sales as reported to Bureau of Mines.
3/ Data not available.

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TABLE 29. - Wholesale prices per ton of typical mixed fertilizers in different groups of states, 1919-29

Year	New England States	Middle Atlantic States	South Atlantic States		South Central and Southwest States	Mid-West and Northwest States
	5-8-7	3-8-4	3-8-3	2-10-2	2-10-2	2-12-2
1919	$94.25	$61.57	$55.68	$44.45	$48.16	$49.93
1920	66.99	47.15	43.99	37.58	40.78	41.15
1921	61.79	44.46	39.52	34.61	39.25	34.79
1922	47.32	29.07	28.59	26.22	31.28	28.19
1923	37.08	25.04	26.26	23.66	28.53	28.65
1924	40.00	23.91	21.38	19.19	27.11	28.65
1925	41.34	26.44	22.80	20.44	26.01	28.10
1926	38.77	26.44	22.80	20.44	25.96	28.10
1927	28.09	21.32	19.00	16.70	30.46	25.41
1928	34.50	28.87	22.90	20.44	23.84	26.20
1929	34.15	28.79	22.40	19.96	24.78	26.19

Source: Collings, G. H., Commercial Fertilizers: Philadelphia, 1934, p. 273. (Probably compiled from National Fertilizer Association data.)

TABLE 30. - Prices paid by farmers of the United States for different grades of fertilizer in 1928 (Per net ton of 2,000 pounds)

Grade	Low price	High price	Grade	Low price	High price
5-7-5	$30.00	$45.00	0-10-10	$28.50	$36.70
1-8-4	22.00	29.55	2-10-2	23.70	37.50
2-8-2	21.18	32.00	3-10-3	26.00	42.65
2-8-5	26.10	38.00	4-10-4	26.00	41.75
2-8-10	30.79	48.00	0-12-5	22.80	30.10
3-8-3	21.80	36.35	2-12-2	27.00	40.00
3-8-4	30.00	44.00	2-12-6	31.00	43.00
3-8-5	26.00	42.50	3-12-3	28.00	37.00
3-8-6	34.50	41.60	4-12-4	28.00	48.00
4-8-7	34.00	48.00	0-14-4	28.00	34.00
5-8-5	30.50	41.00	5-15-5	39.50	51.00
5-8-7	37.00	50.85	2-16-2	33.40	50.00
1-9-4	23.50	35.50	16 percent superphosphate	13.00	29.15
2-9-3	22.84	37.85	Nitrate of soda	40.00	70.65
3-9-3	22.58	29.50	Muriate of potash	40.00	60.00
0-10-4	21.30	27.50	Kainite	13.00	26.00

Source: Collings, G. H., Commercial Fertilizers: Philadelphia, 1934, p. 272.

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WAGES AND OUTPUT PER WAGE EARNER

In the last analysis wages constitute a large factor in the delivered cost of fertilizers, as of other manufactured goods, but according to the industrial classifications set up by the Census only 7.65 percent of the value of products was expended for wages in 1929 and only 9.0 percent in 1919. Although unit wages have increased substantially during the past 30 years they represent a smaller and smaller percentage of the total value of products. Salaries comprised 4.0 percent and 4.1 percent of the value of products in 1929 and 1919, respectively, whereas the cost of materials for the same years was 67.5 and 64.5 percent, respectively. Fuel and purchased energy are minor items in cost, representing only 1.9 and 1.2 percent of the gross value in the years mentioned.

Due to the fact that the industry is conducted so largely in the South, the average wages paid are somewhat lower than in other manufacturing industries; whereas the figures for States north of the Mason and Dixon line generally show an average of over $1,000 a year, the average for many southern States is under $750 a year, based on full-time employment. Actually, however, operations are highly seasonal, coming to a peak in March or April and dropping rapidly to a minimum in June and July. Even in the large plants in Maryland only half as many men are employed in the slack summer season as in the early spring, and in some States the ratio is scarcely 10 percent. Florida and California both make an excellent showing in this respect, employment in the latter State during the minimum month of 1929 being 71.4 percent of that for the maximum month, whereas the average for the country as a whole, as shown in the following table, was only 38.5 percent.

Although wages are rather low the average output per employee is high, and the value added by manufacture per wage earner compares favorably with the average for manufacturing industries, amounting to $3,480, or more than four times the average wages paid in 1929.

TABLE 31. - Average wages and output per wage earner in the fertilizer industry, 1899-1931

(Data from U. S. Bureau of Census)

Year	Wage earners (average for year)	Wages paid	Average wages per year	Employment index 1/	Value of product per wage earner	Value added by manufacture per wage earner
1899	11,581	$ 4,185,289	$361	2/	3,860	1,355
1904	14,184	5,127,147	361	2/	3,980	1,215
1909	18,310	7,477,179	408	48.7	5,680	1,880
1914	22,815	10,532,005	462	44.0	6,710	1,980
1919	26,296	25,363,132	965	54.9	10,690	3,655
1921	16,898	16,025,728	948	46.2	10,670	2,095
1923	18,572	16,365,324	881	44.3	9,860	2,970
1925	19,644	17,743,327	903	41.7	10,530	3,510
1927	18,612	17,649,661	948	2/	10,230	2,810
1928	20,926	17,883,925	855	38.5	11,110	3,475
1931	14,551	12,145,966	835	35.9	10,610	3,290

1/ Percent employed in minimum month compared to maximum month in year.
2/ Data not available.

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It is interesting to compare these figures with those for British industry. The British Census shows for fertilizer, disinfectant, glue, and allied industries a total output (sales value) of £5,717,000 in 1930 compared with £7,695,000 in 1924. Due to price changes, the volume of production in 1930 probably was as much as 14 percent larger than in 1924. Expenditures for materials dropped from £4,921,000 to £3,116,000 and the average number of persons employed declined from 9,661 to 8,548, but the net output (value added?) per person employed increased from £287 to £304, due in part perhaps to the increased mechanical power used - from 34,200 horsepower in 1924 to 35,200 in 1930. The best efficiency was reported in plants employing 100 to 199 persons, and even plants with 25 to 49 workers showed a higher output per employee (£308) than those with 200 to 500 workers (£282). The average wage of all operative staff in chemical industries in 1930 was £140, but the average for the fertilizer and allied industries was somewhat less, only £129. Of the 8,548 employees in 1930, 5,889 were male operatives, 1,124 were female operatives, and 1,506 (1,124 male and 382 female) were classed as administrative, technical, and clerical staff.

THE INDUSTRY IN FOREIGN COUNTRIES

From various reports of the Chemical Division of the U. S. Bureau of Foreign and Domestic Commerce alone it would be possible to compile a fairly complete balance sheet of the consumption and foreign-trade statistics of most of the leading countries of the world, but such detailed analyses are beyond the scope of the present paper, although they doubtless would shed much light on current trends of domestic exports and imports. International agreements afford a perennial source of interest with respect to all three of the leading plant foods. Attempts to coordinate the confusion in nitrogen production afford an especially complex study, as the flow of events seems to favor now the synthetic and then the Chilean or again the byproduct producers. The potash situation, formerly securely controlled by the German cartel, occasionally gets out of hand as more and more sources of supply are tapped. On the other hand, phosphate-rock suppliers apparently managed in 1933 to reach some degree of agreement after years of strife.

Germany has continued to be the leading producer of nitrogen and potash and also one of the largest consumers of artificial fertilizers in the world. In metric tons of major plant foods, German consumption increased from 185,000 (N), 555,000 (P_2O_5), and 430,000 (K_2O) in 1914 to 430,000 (N), 553,000 (P_2O_5), and 783,000 (K_2O) in 1929. Even in 1932, a great deal more nitrogen and potash were consumed in Germany than in 1914, although phosphoric acid consumption was greatly reduced. Curtailment of phosphate consumption is especially marked in years when efforts to reduce all imports have been most active. Moreover, due in part to general conditions and in part to a tendency to acidity in German soils, a large part of the phosphate is supplied by basic slag, so this trend, if continued, is not fully reflected in phosphate rock requirements. Germany contains 30 million hectares of arable soil, and few countries except the Netherlands and Belgium fertilize as intensively. Average consumption of artificial fertilizer has been reported to the Prussian Ministry of Agriculture as follows:

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TABLE 32. - Average consumption of artificial fertilizer in Germany

Crop year	Nitrogen (N)		Phosphoric acid (P_2O_5)		Potash (K_2O)	
	Kilos per hectare	Index no.	Kilos per hectare	Index no.	Kilos per hectare	Index no.
1913-14	6.0	100	18.0	100	15.9	100
1925-26	11.4	120	13.1	73	21.0	132
1928-29	14.6	243	18.6	103	26.6	167

German synthetic nitrogen producers have introduced a variety of new mixed fertilizers. The various special complete fertilizer mixtures selling under the trade name Nitrophoska are products of the I. G. (German dye trust). A combination of ammonium chloride and limestone, Kalk-Ammon, is supplied by another concern for use on acid soil. Leuna saltpeter and Montansaltpeter contain both sulphate and nitrate of ammonia. In 1934, effective until June 30, 1940, when the present nitrogen-cartel agreement expires, the German Government placed a prohibition upon the erection of new plants for production of synthetic ammonia or calcium cyanamide and upon increasing capacity of existing plants.

The Netherlands is one of the leading world producers of superphosphates and occupies an important place in the sulphate of ammonia trade, both in its own right and in forwarding exports of German origin. Normally the Netherlands uses more artificial fertilizer per acre of crop and improved pasture and hay land than any other country; consequently, its home consumption is fairly large despite its small area.

France19/ shared the world-wide expansion of fixed-nitrogen plant capacity. In 1913 scarcely one fourth of French needs of nitrogenous plant food was supplied domestically, but the proportion rose to 32 percent in the 1926-27 season, 62 percent in 1931-32, and about 87 percent in 1933-34, when consumption amounted to 158,200 metric tons compared with the 1929 maximum of 177,000 tons. Imports of nitrogen under all categories have consequently diminished (except perhaps as regards calcium nitrate); only those of sodium nitrate are still important, and even they have been greatly reduced. Although still far behind Germany, France far outstrips all other countries in production of potash salts, but home consumption is astonishingly small - only about one seventh as much per hectare as is used in the Netherlands or Germany. Formerly a heavy exporter of superphosphates, France began in 1932 and again in 1933 to import approximately 10 percent of her own home requirements. Instead of a surplus of some 300,000 tons annually, there has recently been a net deficit of some 100,000 tons. Exports of basic slag exceeded

19/ The figures used in this paragraph are taken mainly from an article by Pierre Gounod: Les industries chimiques au cours de la dernière période décennale: Chim. et ind., spec. no., October 1934, pp. 120-3.

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a million tons in 1928-29 (about two thirds of the production) but were subsequently reduced because of the curtailment in steel making.

Great Britain has ranked close to Germany in production of sulphate of ammonia and due to smaller home demand has been the largest exporter of this product, finding its principal markets in the Far East. With respect to superphosphates as well as potash salts, British imports far exceed exports, but as regards nitrogen the United Kingdom has a large net surplus even after allowance is made for the heavy imports of sodium nitrate for industrial purposes. In addition to the ammonia at gas works and byproduct plants, synthetic ammonia has been produced in generally growing quantities. Basic slag and mixed fertilizers are items of considerable importance in British export trade.

Various other European countries are heavy producers as well as consumers of fertilizers, and several of them carry on a fairly substantial export trade. The synthetic nitrogen industries of Norway, largely dominated by German policies and employing considerable French capital, may be mentioned. Belgium likewise has a nitrogen surplus. Spanish potash exports claim increasing attention. The U. S. S. R., however, now promises to play a more important role in the fertilizer industry, having made rapid strides toward developing a large export surplus. The Solikamsk potash resources are now known to be of huge proportions, and the Khibiny apatite industry has raised the Soviet Union to fourth place among sources of mineral phosphates.

Japan has become a growing factor in world trade in fertilizers. As recently as 1929 two thirds of Japan's nitrogen fertilizers were being imported, but in 1934 the newly created domestic industry was preparing to supply a substantial export surplus. Except for a small and diminishing contribution from the mandated islands in the South Seas, the Japanese superphosphate industry depends for its raw material upon phosphate-rock imports from Egypt, the United States, and Oceania. Nevertheless it has developed considerable export trade, recently making rather a strong bid for business along the Pacific coast of the United States. The Far East generally, however, is an import market, and even Australia and New Zealand import basic slag, potash, and nitrates, although conducting a fairly large local industry converting raw rock from Nauru and Ocean Islands into superphosphates.

South American countries are buyers of American and European fertilizers on a growing scale; but their main contributions to world trade are exports of guano, Chilean nitrate of soda, and sundry products from slaughterhouses tributary to the River Plate.

Canada is both a major market for American fertilizers and fertilizer materials and a source of imports into the United States. Potash and phosphates comprise the principal fertilizer materials shipped into the Dominion, and cyanamide from Niagara Falls plants is the leading export item, although fish meal and manufactured fertilizers likewise are rather important. A little apatite is produced in the Buckingham district of Quebec, but the main supply of the Consolidated Mining & Smelting Co., Ltd., phosphate plant at Trail, B. C., is obtained from Idaho and Montana, although some work has been done on a deposit of phosphate rock in the Crow's Nest district of British Columbia.

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